

How Mockups, a Key Engineering Tool, Help to Promote Science, Technology, Engineering, and Mathematics Education

Harry E. McDonald IV¹

NASA Undergraduate Student Research Program Intern, Houston, Texas 77058

The United States ranking among the world in science, technology, engineering, and mathematics (STEM) education is decreasing. To counteract this problem NASA has made it part of its mission to promote STEM education among the nation's youth. Mockups can serve as a great tool when promoting STEM education in America. The Orion Cockpit Working Group has created a new program called Students Shaping America's Next Space Craft (SSANS) to outfit the Medium Fidelity Orion Mockup. SSANS will challenge the students to come up with unique designs to represent the flight design hardware. There are two main types of project packages created by SSANS, those for high school students and those for university students. The high school projects will challenge wood shop, metal shop and pre-engineering classes. The university projects are created mainly for senior design projects and will require the students to perform finite element analysis. These projects will also challenge the undergraduate students in material selection and safety requirements. The SSANS program will help NASA in its mission to promote STEM education, and will help to shape our nations youth into the next generation of STEM leaders.

Nomenclature

STEM	=	Science, Technology, Engineering, and Mathematics
PE	=	Participatory Exploration
CEV	=	Crew Exploration Vehicle
LFM	=	Low Fidelity Mockup
MFM	=	Medium Fidelity Mockup
CAD	=	Computer Aided Design
SAA	=	Space Act Agreement
PDR	=	Preliminary Design Review
CDR	=	Critical Design Review
CAR	=	Customer Acceptance Review
HUNCH	=	High Schools United with NASA to Create Hardware
SSANS	=	Students Shaping America's Next Spacecraft
IGES	=	Initial Graphics Exchange Specification
T-STEM	=	Texas Science, Technology, Engineering and Mathematics

I. Introduction

In recent years the United States of America, historically known to be a leader in innovation and science, has been falling behind. In a study of 15 year-old students around the world the U.S. ranked 28th in math literacy and 24th in science literacy as well as 20th in college graduates in natural science and engineering.¹² To counteract these falling numbers the U.S. government and grass roots organizations have made a large push in science, technology, engineering and mathematics (STEM) education for the nation's youth. President Obama is taking a progressive approach towards STEM education by making a goal for American students to go from the middle of the pack to the top in science and math achievements over the next decade.¹

¹Fall USRP Intern, EA3 Systems Architecture and Integration, NASA JSC, Kansas State University

“Reaffirming and strengthening America’s role as the world’s engine of scientific discovery and technological innovation is essential to meeting the challenges of this century,” said President Obama. “That’s why I am committed to making the improvement of STEM education over the next decade a national priority.”¹

NASA is at the center of technological and scientific achievements in America and the world. NASA needs sharp young minds to continue to be a leader in innovation. Because of the falling numbers in America’s educational system NASA has started to increase its efforts in educational outreach and STEM education.

NASA is composed primarily of scientists and engineers. With the baby boomer generation on the verge of mass retirement, NASA needs to continue to bring in STEM majors to sustain its workforce and attained knowledge. To make sure NASA can still recruit from the best and brightest NASA has developed three main educational goals:²

- Strengthening NASA and the Nation’s future workforce
- Attracting and retaining students in science, technology, engineering and mathematics, or STEM disciplines
- Engaging Americans in NASA’s mission

Along with these goals, NASA has created the office of Participatory Exploration (PE). PE is described as an active involvement of individuals in NASA’s research and exploration.³ This office has been created to allow for a more interactive approach between the public and NASA. PE allows the public to go beyond participating in outreach programs, and creates a mechanism for the public to be a contributing member to a project without being a government employee. PE can assist NASA in its educational goals by encouraging youth as well as adults to pursue STEM activities in efforts to help NASA in innovation and exploration.

II. Human in the loop evaluations

Mock-ups have been used at NASA in the design of spacecraft and hardware since the Gemini program. Four main objectives mockups help to accomplish are design development, human in the loop testing for flight design verification, astronaut training, and education of the public about the various NASA programs. Currently, the main focuses of the Orion mockups are human in the loop verification tests. Human in the loop tests are used to evaluate human interfaces in the Crew Exploration Vehicle (CEV). Tests include all astronaut activities that need to occur inside the spacecraft such as ingress into the CEV, egress out of the CEV, and interaction with the vehicle displays, controls and various equipment. Tests are done by NASA focusing on human interfaces both in a gravity environment and on orbit in weightlessness. Two mockups that will aid NASA in this objective are called the Low Fidelity Mockup (LFM) and the Medium Fidelity Mockup (MFM).

The fidelity of the hardware is based on Table 1 and following definitions from Ref. 4.

Table 1. Fidelity Classification Matrix⁴

Functional Class	A. Functionally Active	B. Operable	C. Static
Flight assembly tolerance Similar materials Exact configuration	IA	IB	IC
Relaxed assembly tolerance ($\pm 0.25''$) Mixed materials Approximate configuration	IIA	IIB	IIC
Approximate dimensions ($\pm 0.50''$) Optional materials Appropriate configuration	IIIA	IIIB	IIIC

A. DEFINITIONS

Functionally Active - The capability of functionally replicating the stimuli, processes and/or responses of the original article. The mockup article shall respond in a manner simulating the original (e.g., a light fixture shall light when the switch is toggled, or hand controller or keypad input invokes a physical response to the evaluator).

Operable - The capability of functionally replicating the general movement of the original article without a response to the evaluator (e.g., a light fixture does not light when the switch is toggled but the light and switch are present, or hand controller / keypad is physically present and moveable, but does not invoke a simulated response).

Static - No active stimuli, processes or responses to the evaluator (e.g., photographic or volumetric representations of light, switches, hand controllers etc.).

Class I: Flight Assembly Tolerance – Conforms to flight (or ground) article dimensions.

Similar Materials – Materials are of the same family and characteristics as the flight article, but are not necessarily the same grade.

Exact Configuration – Appearance is like flight article in all aspects.

Class II: Relaxed Assembly Tolerance – Not held to flight specifications; margins defined by requirements document.

Mixed Materials – Materials meet general characteristics of flight article and optimally support the intended function, but need not be of the same family, grade or specification.

Approximate Configuration – Appearance is similar to flight article (size, shape, color, orientation, location, etc.).

Class III: Approximate Dimensions - Not held to flight dimensions; greater tolerance given to dimensions as specified in requirements document.

Optional Materials – No restrictions on material selection provided the end item meets the requirements.

Appropriate Configuration – Appearance to depict the design or anticipated concept.

The LFM is mainly composed of volumetric hardware mockups in the IIC to IIIC category, with a few articles in the IIB category. A low fidelity hardware mockup is usually constructed out of foam board, or other inexpensive and easy to use construction materials. The LFM is useful for initial design assessments as well as human factors in layout of the hardware inside the crew cabin. As flight models of the hardware inside the cabin change, the LFM allows for rapid prototyping, installation and assessment.

The MFM currently is comprised only of a IIB fidelity shell of the CEV. Currently the budget for outfitting the MFM is minimal, and most work by NASA employees and contractors is on hold. This mockup will consist of much higher fidelity hardware ranging from IB to IIC fidelity. The MFM will be used for the final stages of design development similar to efforts that have been done in LFM, but will have more dimensionally correct human interfaces and hardware locations. In addition, the MFM will provide the fidelity needed to conduct final spacecraft verification of a number of human focused vehicle requirements that must be formally verified before the spacecraft will be approved for flight.

III. Mockups relating to STEM

Mockups can be great tools for increasing STEM education and interest in the students today. They can be directly accessed by students, allowing for the mockups to be a hands on learning tool. Mockups can be seen everywhere from miniature buildings to full scale International Space Station layouts. They have been a great tool when informing the public about complex hardware designs. Because mockups are not space flight hardware, students can help to design and construct the hardware inside the mockup with little engineering background. Requirements for the mockup hardware can be created that help to further the student's education in STEM and hopefully increase their interest in the subject as well. The Orion Cockpit Working Group currently uses interns to update the LFM to the latest flight design, and is kicking off an effort to have university and high school students outfit the MFM.

A. Construction of Low Fidelity Hardware

The main objective of an intern working on the LFM and MFM is to update the hardware installed on forward bulkhead and the barrel walls according to the latest flight computer aided design (CAD) model. This is done through the following steps:

1. Obtain the latest flight CAD model
2. Obtain the latest excel database of flight hardware assemblies and parts
3. Reference old flight models to verify what parts are to be installed in the crew cabin
4. Search the database for the part number or part name that is to be updated
5. Pull up the part model in ProEngineer (ProE) for dimensioning
6. Update or Create a forward bulkhead view in the flight model to accurately depict where the hardware is located
7. Construct the hardware to volumetric representation of the flight design
8. Install hardware within 0.5 inches of the flight hardware location

Volumetric representation gives interns room for creativity when constructing the mockup hardware. Decals are heavily used in the LFM to give the user an understanding of the complicated structures as well as approximate location of switches, knobs and connectors. The fidelity of most of the hardware is currently in the process of being updated from IIC to IIB. Because of the budget, the crew systems flight hardware design development is mostly on hold, which provides a unique opportunity for the fidelity of the hardware to increase due to a stable design.

The main obstacle when installing hardware is what to reference measurements from. If the intern measures from previously installed hardware major error can occur due to an error in the placement of the referenced hardware. To overcome this problem lines have been drawn on the mockup that represent the Y and Z planes in the flight model. Distance and angle measurements can be taken from these planes to accurately place the mockup hardware.

B. Outfitting the Medium Fidelity Mockup

Budget pressures have limited the ability to outfit the MFM by NASA employees. Due to these pressures, the Cockpit Working Group has created an educational outreach program called Students Shaping America's Next Spacecraft (SSANS). SSANS will incorporate high schools, community colleges, vocational schools and universities to outfit the MFM. The wide range of project requirements is the driving force behind involving so many levels of education. The project packages are developed to challenge the students in the design and fabrication of the hardware, and to guide them in the engineering design process. SSANS is taking the course of action to team up with existing programs as well as developing new partnerships. The main legal agreement that needs to be in place for NASA to interface with a school is a Space Act Agreement (SAA).

The SAA is designed to clearly define the roles and limitations of NASA and the schools so that ultimately the final product can be used by NASA. A draft SAA for SSANS is attached in Appendix A. The SAA highlights the requirements from NASA such as providing a mentor, providing agreed upon materials necessary for the project, and outlining how the project packages are constructed. The SAA also outlines such things as intellectual property rights, the ability of NASA to have multiple partners in outfitting the mockup, and liability issues. It is recommended that the NASA legal department co-author the SAA with the program members. New Space Act Agreements are only needed when there is no preexisting agreement between NASA and the associated partner.

C. Partnering with Existing Programs

There are a few programs already formed that have allowed the SSANS program to rapidly move forward with project package delivery. The three main programs that SSANS is looking to partnering with are High School Students United with NASA to Create Hardware (HUNCH), Texas STEM (T-STEM) centers and the Texas Design Challenge (TDC).

1. High School Students United with NASA to Create Hardware

HUNCH was started in 2003 by a JSC engineer.⁶ HUNCH has the ability to manufacture as high as IB fidelity mock-up hardware for drastically lower prices than NASA would pay for contract work. NASA supplies the material, mentoring and JSC tours, whereas the high school provides the student design and construction labor along with the tools necessary for construction. An example of what HUNCH schools can accomplish is highlighted on NASA.gov when students at Clear Creek High School manufactured space station training lockers that would have cost NASA as much as \$10,000 to manufacture.⁵ HUNCH schools around the Houston area are able to work with metal, wood, plastics, and fabrics. For the initial projects SSANS program members will meet with each potential school to assess the schools capabilities for SSANS projects. For future projects an application will be used and the

schools will apply for the SSANS projects. HUNCH can be a great tool to stream line mock-up hardware fabrication. HUNCH has SAAs established with many local schools in the Houston, Texas area, which will allow for projects to be started as early as December 2010.

2. *Texas Science Technology Engineering Mathematics Centers*

T-STEM centers, like HUNCH, have a direct relationship with high schools and vocational schools that meet SSANS requirements for MFM outfitting projects. SSANS is looking to partner with the following T-STEM centers: University of Texas Medical Branch T-STEM, Texas Tech University T-STEM and the University of Texas Tyler T-STEM. The mission of the T-STEM centers is highlighted on the official T-STEM website.

“The Texas Science, Technology, Engineering and Mathematics Centers address the challenges of tomorrow’s technology-driven economy by researching, developing, and supporting best practices in science, technology, engineering, and mathematics education for K-12 schools.”⁷

T-STEM centers are focusing their efforts to counteract the decreasing technical competency in America’s students. They promote and develop projects such as SSANS as well as develop curriculum that encourages and pushes students to become more technically minded. SAA agreements have not previously been drafted for T-STEM schools SSANS is looking to partner with. An example draft of the SAA for one of the centers is attached in Appendix A.

3. *University Partnering*

Projects that require finite element analysis and experience in various engineering disciplines will be given to universities. Universities will either be hand selected for new partnerships or be a part of an existing program like the Texas Design Challenge. When partnering with a university SSANS mentors will hold regular meetings with the design team to mentor them on the design challenges of the SSANS project. The projects developed for this package will be created as if the work was given to a contractor, and the mentors will hold the student team responsible for meeting all the safety and design requirements.

4. *Texas Space Grant Consortium Texas Design Challenge*

The Texas Design Challenge is sponsored by the Texas Space Grant Consortium (TSGC). This program allows university students around the state of Texas to participate in mission relevant engineering design problems.⁸ NASA mentors submit a design problem to TSGC and TSGC helps NASA to interface with the universities and develop project requirements. TSGC has an extensive amount of project guidelines listed on its website www.tsgc.utexas.edu/challenge. The SSANS program will potentially submit multiple university projects to TSGC. Using the design challenge as the mechanism for the university projects benefits SSANS because the guidelines and instructions for mentors and students have already been developed, SAAs already exist, and the professors are familiar with NASA design projects. Funding for the projects comes from TSGC, which benefits SSANS due to a small budget.

D. **Creating Student Projects**

There is a wide variety of student projects for outfitting the MFM. The SSANS program is looking for IIB to IIC level of fidelity in the hardware depending on the project type and educational level of students. There are two main project categories, high school related projects and university related projects. High school projects include the smaller or less-complex pieces of non-load-bearing hardware. The requirements for these projects focus on the hardware visual appearance and do not require significant materials or engineering knowledge. University projects require much more understanding in the areas of material selection, stress analysis, and the engineering design process. When creating packages, attention is given to the student’s educational level so that the students can have design challenges suited for that level. For all the projects a project outline will be given to the school detailing the project guidelines and requirements. An example of a project outline is given in Appendix B. Included with the project outline will be either drawings or CAD models that the students will base their hardware designs from.

1. *High School Projects*

High school projects are aimed at students enrolled in machine shop, wood shop, pre-engineering or home economics classes. They will consist of hardware to be mounted on the forward bulk head and interior walls of the CEV. The project package will outline all the requirements that SSANS sets for the project. For SSANS projects there will be a requirement of three design reviews, which include the preliminary design review (PDR), critical design review (CDR) and a customer acceptance review (CAR). The package will outline what is needed for each design review. The following is an example of what the project outline would include about the PDR from the

Auxiliary Bus Control Unit project.⁹

PRELIMINARY DESIGN REVIEW (PDR)

A PDR shall be conducted to ensure that the proposed design concepts comply with the requirements. The PDR shall, at a minimum, consist of a review of the following:

- a. Engineering design
- b. Structural analysis plan
- c. Design concepts for functional / semi-functional components
- d. Fabrication plan and drawing tree / list
- e. Mockup Installation Concept
- f. Hazard List – Hazards to personnel using the ABCU mockup once installed in the Orion mockup

Electronic copies of all material to be presented at the PDR shall be submitted to NASA five working days prior to the scheduled PDR. PDR drawings shall depict approximately 80 percent of all materials and parts to a 30 percent level of detail. The preliminary structural analysis shall include; structural geometry, member sizes, load conditions, support conditions and trainer weights, and shall be ready for review 5 days prior to the PDR.

Students must use the engineering design process to understand the requirements and develop the hardware design as well as a plan for implementing the hardware in the MFM. Safety is a large part of the requirements that will challenge the students to come up with unique designs. SSANS mentors will work with the high schools extensively to make sure they are on the right track when constructing the project hardware. If the dimensional fidelity is lowered, schools should give reasons in their PDR. Students have the freedom to be creative in their redesigning of the flight model. For hardware that is to be installed on the forward bulkhead students must provide high level information regarding structural analysis. The students must also provide information about how the hardware will be supported and able to interface with humans without causing a safety hazard such as falling off.

2. University Projects

The packages of this type either directly support the weight of the human user, or are heavy enough that constructing and mounting them is a major design challenge. These projects are proposed for upper level design courses in universities. Stress Analysis will need to be done using the finite element method to show that material selection, mounting hardware, and modified flight design are strong enough to hold the specified load in the package. The project outline document will be set up in the same manner as the high school projects but with more advanced requirements to challenge the undergraduate engineering design team. CAD models will be given to show the dimensions that the group must adhere to. Most hardware will still be required to meet fidelity IIB and IIC standards; however, because of the advanced knowledge of the design teams some additional hardware will be required to include fidelity of IIA, providing flight-like hardware.

3. Creating Computer Aided Design Models

CAD models will be used whenever possible. The more practice students have with CAD the better experience they have in the engineering design process. Students can use the CAD model to pull the desired design dimensions as well as get a better understanding of what the flight hardware looks like. Based on the CAD model students will either create their own CAD models or drawings of their hardware design. They will then use these models to present at design reviews as well as reference the drawings when constructing the mockup hardware.

When creating CAD models, pictures, and drawings for the project packages, protection of sensitive information must be addressed. The CAD models and drawings must give the minimal amount of detail about the hardware and the overall design of the CEV due to ownership of the model by Lockheed Martin, and because space flight is a national security issue. Therefore, only the most needed dimensions can go out in the packages.

All the hardware in the ProE flight model references other parts. To overcome the problems of referencing and sensitive data the flight hardware models are shrinkwrapped. Shrinkwrapping in ProE saves the models surfaces, but does not save how the model was constructed. This eliminates much of the sensitive material about the hardware, and makes it possible to send out in project packages. The shrinkwrapped part is then saved as an Initial Graphics Exchange Specification (IGES) file. An IGES file is a common readable file among all CAD software.

IV. Results for SSANS

SSANS is still in its infancy. Preliminary project packages are planned to go out to select schools in early December 2010. Initial project packages have been developed for the HUNCH program. These will help the mentors evaluate their developed requirements for high school students as well as educate themselves on what is needed for the high school students to be successful.

There have been a total of 17 project packages created, all relating to high school projects. Figure 1, below, is an example of what the high school students will use as a reference when constructing their hardware.

A power point outline has also been created for the students to document their work. The groups will use this document in the design reviews and other project presentations. It will also serve as a standard form that will be easy to understand for the engineers of SSANS. The following list is an outline of all the main topics covered in the power point.

- Project Schedule
- Requirements outline
- Initial Design
- How the team plans to meet requirements
- Proof showing that the requirements were met with approved design
- Final Design and Fabrication Outline
- Fabrication
- Acceptance Testing

During discussions among the various possible partners of the SSANS program a project description outline was created. This document served as the initial introduction to the various programs about the possible projects. It outlines all the major projects explaining high-level project requirements, and shows overview pictures of what the students will be doing.

This document will be used further when entering into partnerships with new schools and programs.

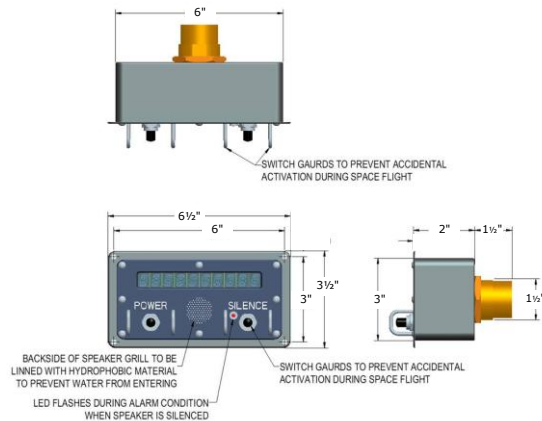


Figure 1. Contingency Gas Analyzer Dimensions⁹

V. Results in the Construction of Low Fidelity Hardware

The following is an example of an intern's accomplishments during a 15 week tour in the fall of 2010.

A. Internship Example from Fall 2010

I have updated the LFM's forward bulkhead to the latest flight model. For this objective I used a wide range of fidelity when constructing the hardware. Figure 2, 3, and 4, to the right, help to explain the different levels of fidelity incorporated in the LFM. The speaker unit is a mixture of IB and IIB fidelity and the positive pressure relief valve is an example of IIC fidelity. The speaker unit will be installed in the MFM and will be an example for the SSANS student projects. Table 2, shown on the next page, lists the hardware I have updated as well as the level of fidelity it is currently in.



Figure2. Positive Pressure Relief Valve



Figure3. Lighting Power Module



Figure4. Lighting Power Module

Table 2. Completed Hardware

Hardware	Fidelity Level
Speaker Unit	IB, IIB
Power Equipment Panel	IIC
Audio control Speaker Unit	IIC
Snorkel Fan	IIC
Zone ½ Lighting Power Module	IIB
Positive Pressure Relief Valve	IIC
Cabin Return Diffuser	IIC
Docking Light	IIB, IIC

VI. Conclusion

Construction of mockup hardware can be a very useful tool for NASA to promote STEM education. The projects that students work on help them to advance in technical subjects, and would promote NASA to the next generation. The projects stimulate the student's minds technically because of the design problems of material selection, accurate volumetric representation, and safety requirements. The SSNAS mockup projects will become a vital part of NASA's path to a successful new Orion spacecraft, allowing students to take pride in their work and pride in NASA itself.

During the process of construction students will have access to NASA engineers. This can be a great resource for the students to ask questions about engineering, the project they are working on, and about NASA in general. The engineers can help to guide the students toward STEM degrees by helping them get excited about engineering and science. NASA's mission towards education is of high importance, and involving engineers in this mission is key towards raising interest in STEM related majors.

Internships can be a great way to get students interested in NASA and its wide range of projects. By including students in NASA programs, they can go back to their various communities and promote STEM by presenting about the projects they worked on. NASA's outreach in states that do not have a NASA center is limited. Interns can help to expand this outreach when they go back to communities where there is no center. Internships also help to shape students into successful engineers. By including students in engineering projects early, NASA is speeding up the learning curve of young engineers allowing them to be ready to take on greater challenges when stepping into the work force. John F. Kennedy once said, "Our progress as a nation can be no swifter than our progress in education. The human mind is our fundamental resource."^{10,11} This statement helps to sum up why NASA's number one priority should be to promote STEM education. Without achievement in America's student population then NASA, a leader in innovation, will cease to exist.

Appendix A.

NONREIMBURSABLE SPACE ACT AGREEMENT
BETWEEN
NASA
AND
THE UNIVERSITY TEXAS MEDICAL BRANCH AT GALVESTON
FOR AND ON BEHALF OF
THE SOUTHEAST REGIONAL T-STEM CENTER¹⁴

ARTICLE 1. AUTHORITY AND PARTIES

In accordance with The National Aeronautics and Space Act of 1958, as amended (42 U.S.C. 2473(c)), this Agreement is entered into by and between the **NASA Lyndon B. Johnson Space Center** located at 2101 NASA Parkway, Houston, TX 77058 (hereinafter referred to as “NASA JSC”, “JSC”, or “NASA”) and **The University of Texas Medical Branch at Galveston**, located at 301 University Boulevard, Galveston, TX 77555 (hereinafter referred to as “UTMB” or “Partner”), for and on behalf of its **Southeast Regional T-STEM Center** (hereinafter referred to as “SRT-STEM Center”). NASA and Partner may be individually referred to as a “Party” and collectively referred to as the “Parties.”

ARTICLE 2. PURPOSE

NASA JSC will enter into a Space Act Agreement with Partner and the SRT-STEM Center in order to pursue the “Students Shaping America's Next Spacecraft” Program currently being managed at UTMB. The SRT-STEM Center facilitates collaboration between colleges, high schools and other institutions (“SRT-STEM Participants”) to bring real-world engineering projects into the classroom to foster interest and skill development in the areas of science, technology, engineering, and mathematics (“STEM”). In the first phase of this project, NASA will partner with the SRT-STEM Center to allow students to design and fabricate Orion Medium Fidelity Mock-up (MFM) components and participate in other relevant educational projects with guidance and mentoring from experienced NASA engineers. Through this partnership, the SRT-STEM Center will fulfill its mandate to provide an interesting, challenging real-world education experience to its affiliated schools. This partnership will allow Johnson Space Center to further advance its outreach objectives and STEM education ideals. It will also allow for further dissemination of information about the unique nature of NASA development hardware and space craft design evaluations into academia.

ARTICLE 3. RESPONSIBILITIES

A. UTMB and the SRT-STEM Center will use reasonable efforts to:

1. Serve as an intermediary between NASA JSC and SRT-STEM Participants;
2. Manage the preliminary selection and matching of all schools/classes/students with projects;
3. Coordinate necessary telecommunications tools and/or travel for selected SRT-STEM Participants;
4. Provide NASA with CAD models, electronic presentation materials and relevant analysis as applicable for each project;
5. Participate in formal design reviews for each project;
6. Participate in hardware acceptance review (if applicable) for each project;
7. Participate in project meetings as necessary; and
8. Help coordinate shipping of finished projects to NASA by the SRT-STEM Participants.

B. NASA will use reasonable efforts to:

1. Provide detailed flight vehicle component drawings, mock-up component requirements, and other information to define the use and design trade space for each project;
2. Provide informal mentoring as required to clarify requirements and project parameters;

3. Support formal design reviews with the SRT-STEM Participants;
4. Conduct an early conceptual design review to ensure students meet intents of project requirements, and provide results of this review to UTMB;
5. Conduct a final design review to ensure students meet requirements before fabrication, and provide results of this review to UTMB;
6. Provide agreed upon materials to UTMB or SRT-STEM Participants (as appropriate) for fabrication of mock-up hardware as necessary;
7. Conduct an acceptance review of all design and analysis data as well as any fabricated hardware;
8. Provide documentation of acceptance criteria of student-developed hardware;
9. Conduct other project reviews as necessary; and
10. Arrange for shipping of all agreed upon materials necessary for project performance to UTMB or SRT-STEM Participants (as appropriate).

ARTICLE 4. SCHEDULE AND MILESTONES

The approximate planned major milestones for the activities defined in Article 3 above are as follows:

- | | |
|---|---|
| 1. NASA and SRT-STEM Center will have a preliminary Q&A to refine project requirements. | Approximately one week after team selections |
| 2. NASA and SRT-STEM Center will agree upon project materials and shipment requirements. | Approximately four weeks after team selections |
| 3. NASA will acknowledge acceptance of SRT-STEM Center material requests related to the projects. | Approximately five weeks after team selections |
| 4. SRT-STEM Center will provide NASA with all relevant CAD models, presentation material, pertinent analysis, and fabricated mock-up hardware as applicable for each project. | Approximately two weeks prior to project completion |
| 5. SRT-STEM Center will coordinate shipment of all completed projects to NASA. | Approximately two weeks prior to project completion |
| 6. SRT-STEM Center will coordinate with NASA JSC to hold bi-monthly project meetings, when deemed necessary by both parties. | Approximately bi-monthly |
| 7. NASA and SRT-STEM Center will coordinate a final design review. | Approximately three weeks prior to project completion |

ARTICLE 5. FINANCIAL OBLIGATIONS

There will be no transfer of funds or other financial obligations between the Parties under this Agreement and each Party will fund its own participation and be responsible for its own costs incident to this Agreement. All activities under or pursuant to this Agreement are subject to the availability of funds, and no provision of this Agreement shall be interpreted to require obligation or payment of funds in violation of the Anti-Deficiency Act, Title 31 U.S.C. § 1341.

ARTICLE 6. PRIORITY OF USE

Any schedule or milestone in this Agreement is estimated based upon the Parties' current understanding of the projected availability of NASA personnel, facilities and equipment. In the event that NASA's projected availability changes, Partner shall be given reasonable notice of that change, so that the schedule and milestones may be adjusted accordingly. The Parties agree that NASA usage of its facilities, equipment, and personnel shall have priority over the usage planned in this Agreement. Should a conflict arise, NASA in its sole discretion shall determine whether to exercise that priority. Likewise, should a conflict arise as between two commercial users, NASA, in its sole discretion, shall determine the priority as between the two users. This Agreement does not

obligate NASA to seek alternative government property or services under the jurisdiction of NASA at other locations.

ARTICLE 7. NONEXCLUSIVITY

This Agreement is not exclusive; accordingly, NASA may enter into similar Agreements for the same or similar purpose with other U.S. private or public entities.

ARTICLE 8. LIABILITY AND RISK OF LOSS

1. To the extent permitted by law, each Party hereby waives any claim against the other Party, employees of the other Party, the other Party's contractors and subcontractors at any tier, grantees, investigators, customers, users, and their contractors or subcontractors at any tier (collectively referred to herein as "Related Entities"), or employees of the other Party's Related Entities for any injury to, or death of, the waiving Party's employees or the employees of its Related Entities, or for damage to, or loss of, the waiving Party's property or the property of its Related Entities arising from or related to activities conducted under this Agreement, whether such injury, death, damage, or loss arises through negligence or otherwise, except in the case of willful misconduct.
2. To the extent permitted by law, each Party further agrees to extend this cross-waiver to its Related Entities by requiring them, by contract or otherwise, to waive all claims against the other Party, Related Entities of the other Party, and employees of the other Party or of its Related Entities for injury, death, damage, or loss arising from or related to activities conducted under this Agreement. Additionally, each Party shall require that their Related Entities extend this cross-waiver to their Related Entities by requiring them, by contract or otherwise, to waive all claims against the other Party, Related Entities of the other Party, and employees of the other Party or of its Related Entities for injury, death, damage, or loss arising from or related to activities conducted under this Agreement.

ARTICLE 9. INTELLECTUAL PROPERTY RIGHTS - DATA RIGHTS

1. General

- (a) "Related Entity" as used in this Article 9, means a contractor, subcontractor, grantee, or other entity having a legal relationship with NASA or Partner that is assigned, tasked, or contracted with to perform specified NASA or Partner activities under this Agreement.
- (b) "Data" as used in this Article 9, means recorded information, regardless of form, the media on which it may be recorded, or the method of recording. The term includes, but is not limited to, data of a scientific or technical nature, computer software and documentation thereof, and data comprising commercial and financial information.
- (c) "Proprietary Data" as used in this Article 9, means Data embodying trade secrets developed at private expense or comprising commercial or financial information that is privileged or confidential, and is marked with a suitable restrictive notice, provided that such Data is not known or available from other sources without obligations concerning its confidentiality; has not been made available by the owners to others without obligation concerning its confidentiality; is not already available to the Government without obligation concerning its confidentiality; has not been developed independently by persons who have had no access to the information; and, is not required to be disclosed pursuant to Federal statute, law, regulation, or valid court order.
- (d) The Data rights set forth herein are applicable to employees of Partner and employees of any Related Entity of Partner. Partner shall ensure that its employees and employees of any Related Entity that perform Partner activities under this Agreement are aware of the obligations under this clause and that all such employees are bound to such obligations.

- (e) Data exchanged between NASA and Partner under this Agreement will be exchanged without restriction as to its disclosure, use, or duplication except as otherwise provided in this Agreement.
- (f) No preexisting Proprietary Data will be exchanged between the Parties under this Agreement unless specifically authorized in this Agreement or in writing by the owner of the Proprietary Data.
- (g) In the event that Data exchanged between NASA and Partner includes a restrictive notice that NASA or Partner deems to be ambiguous or unauthorized, NASA or Partner may notify the other Party of such condition. Notwithstanding such a notification, as long as the restrictive notice provides an indication that a restriction on use or disclosure was intended, the Party receiving such Data will treat the Data pursuant to the requirements of this Article 9 unless otherwise directed in writing by the Party providing such Data.

2. Data First Produced by Partner Under this Agreement

In the event Data first produced by Partner (or any Related Entity of Partner) in carrying out Partner responsibilities under this Agreement is furnished to NASA, and Partner considers such Data to be Proprietary Data, and such Data is identified with a suitable restrictive notice, NASA will use reasonable efforts to maintain the Data in confidence and such Data will be disclosed and used by or on behalf of the U.S. Government (under suitable protective conditions) for U.S. Government purposes only.

3. Data First Produced by NASA Under this Agreement

Except for data disclosing an invention owned by NASA for which patent protection is being considered, in the event Partner requests that Data first produced by NASA (or any Related Entity of NASA) in carrying out NASA's responsibilities under this Agreement be maintained in confidence, and to the extent NASA determines that such Data would be Proprietary Data if it had been obtained from Partner, NASA will mark such Data with a restrictive notice and will use reasonable efforts to maintain such marked Data in confidence for a period of [insert a period of up to 5 years, typically 1 or 2 years] after development of the Data, with the express understanding that during the aforesaid restricted period such marked Data may be disclosed and used (under suitable protective conditions) by or on behalf of the U.S. Government for U.S. Government purposes only, and thereafter for any purpose whatsoever without restriction on disclosure and use to the extent permitted by law. Partner agrees not to disclose such marked Data to any third party without NASA's written approval until the aforesaid restricted period expires.

4. Publication of Results

Recognizing that Section 203 of the National Aeronautics and Space Act of 1958 (42 U.S.C. § 2473), as amended, requires NASA to provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof, and that the dissemination of the results of NASA activities is one of the considerations for this Agreement, the Parties agree to coordinate proposed publication of results with each other in a manner that allows each Party a reasonable amount of time to review and comment on proposed publications.

5. Data Disclosing an Invention

In the event Data exchanged between NASA and Partner discloses an invention for which patent protection is being considered, the furnishing Party specifically identifies such Data, and the disclosure and use of such Data is not otherwise limited or restricted herein, the receiving Party agrees to withhold such Data from public disclosure for a reasonable time (presumed to be 1 year unless mutually agreed otherwise or unless such information is restricted for a longer period herein) in order for patent protection to be obtained.

6. Copyright

In the event Data is exchanged with a notice indicating that the Data is copyrighted and there is no indication that such Data is subject to restriction under paragraphs 2 or 3 of this Article 9 (i.e., Data is not marked with a restrictive notice as required by paragraphs 2 or 3 of this Article 9), such Data will be presumed to be published and the following royalty-free licenses will apply:

- (a) If it is indicated on the Data that the Data existed prior to, or was produced outside of, this Agreement, the receiving Party and others acting on its behalf, may reproduce, distribute, and prepare derivative works only for carrying out the receiving Party's responsibilities under this Agreement.
- (b) If the Data does not contain the indication of subparagraph (a) above, the Data will be presumed to have been first produced under this Agreement and, except as otherwise provided in paragraph 5 of this Article 9 and in Article 10 of this Agreement for protection of reported inventions, the receiving Party and others acting on its behalf may reproduce, distribute, and prepare derivative works for any purpose.

7. Data Subject to Export Control

Technical data, whether or not specifically identified or marked, that is subject to the export laws and regulations of the United States and that is provided to Partner under this Agreement will be treated as such, and will not be further provided to any foreign persons or transmitted outside the United States without proper U.S. Government authorization, where required.

ARTICLE 10. INTELLECTUAL PROPERTY RIGHTS - INVENTION AND PATENT RIGHTS

- 1. The invention and patent rights set forth herein are applicable to any employees, contractors, subcontractors, or other entities having a legal relationship with Partner that are assigned, tasked, or contracted with to perform specified Partner activities under this Agreement. Partner agrees to inform such employees, contractors, subcontractors, or other entities of the obligations under this Agreement and to bind them to such obligations.
- 2. Based on the purpose and scope of this Agreement, and the responsibilities of the Parties, NASA has made an administrative determination that the provisions of Section 305(a) of the National Aeronautics and Space Act of 1958, as amended (42 U.S.C. § 2457(a)), do not apply to this Agreement. Therefore, title to inventions made (conceived or first actually reduced to practice) as a result of activities performed under this Agreement will remain with the respective SRT-STEM Participants, students or inventing party(ies), as appropriate. No invention or patent rights are exchanged between or granted by such parties under this Agreement except that NASA and Partner agree to use reasonable efforts to identify and report to each other any invention that is believed to have been made jointly by employees of Partner and employees of NASA (including employees of such NASA contractors, subcontractors, or other entities), and to consult and agree as to the responsibilities and course of action to be taken to establish and maintain patent protection on such invention and on the terms and conditions of any license or other rights to be exchanged or granted by or between NASA and Partner.

ARTICLE 11. USE OF NASA NAME AND NASA EMBLEMS AND RELEASE OF GENERAL INFORMATION TO THE PUBLIC

1. NASA Name and Initials

Partner agrees the words "National Aeronautics and Space Administration" and the letters "NASA" will not be used in connection with a product or service in a manner reasonably calculated to convey any impression that such product or service has the authorization, support, sponsorship, or endorsement of NASA, which does not, in fact, exist. In addition, with the exception of release of general information in accordance with paragraph 3 below, Partner agrees that any proposed public use of the NASA name or initials (including press releases resulting from activities conducted under this Agreement and all promotional and advertising use) shall be submitted by Partner in advance to the NASA Assistant

Administrator for Public Affairs or designee (“NASA Public Affairs”) for review and approval. Approval by NASA Public Affairs shall be based on applicable law and policy governing the use of the NASA name and initials.

2. NASA Emblems

Use of NASA emblems/devices (i.e., NASA Seal, NASA Insignia, NASA logotype, NASA Program Identifiers, and the NASA Flag) are governed by 14 CFR Part 1221. Partner agrees that any proposed use of such emblems/devices shall be submitted to NASA Public Affairs for review and approval in accordance with such regulations.

3. Release of General Information to the Public

NASA or Partner may, consistent with state or Federal law and this Agreement, release general information regarding its own participation in this Agreement as appropriate.

ARTICLE 12. DISCLAIMER OF WARRANTY

Equipment, facilities, technical information, and services provided by NASA under this Agreement are provided “as is.” NASA makes no express or implied warranty as to the condition of such equipment, facilities, technical information, or services, or as to the condition of any research or information generated under this Agreement, or as to any products made or developed under or as a result of this Agreement, including as a result of the use of information generated hereunder, or as to the merchantability or fitness for a particular purpose of such research, information, or resulting product, or that the equipment, facilities, technical information, or services provided will accomplish the intended results or are safe for any purpose, including the intended purpose, or that any of the above will not interfere with privately owned rights of others. Neither the Government nor its contractors shall be liable for special, consequential or incidental damages attributed to such equipment, facilities, technical information, or services provided under this Agreement or such research, information, or resulting products made or developed under or as a result of this Agreement.

ARTICLE 13. DISCLAIMER OF ENDORSEMENT

NASA does not endorse or sponsor any commercial product, service, or activity. NASA’s participation in this Agreement or supply of equipment, facilities, technical information, or services under this Agreement does not constitute endorsement by NASA. Partner agrees that nothing in this Agreement will be construed to imply that NASA authorizes, supports, endorses, or sponsors any product or service of Partner resulting from activities conducted under this Agreement, regardless of the fact that such product or service may employ NASA-developed technology.

ARTICLE 14. COMPLIANCE WITH LAWS AND REGULATIONS

The Parties shall comply with all applicable laws and regulations including, but not limited to, safety, security, export control, and environmental laws and regulations. Access by Partner to NASA facilities or property, or to a NASA Information Technology (IT) system or application, is contingent upon compliance with NASA security and safety policies and guidelines including, but not limited to, standards on badging, credentials, and facility and IT system/application access.

With respect to any export control requirements:

- (a) The Parties will comply with all U.S. export control laws and regulations, including the International Traffic in Arms Regulations (ITAR), 22 CFR Parts 120 through 130, and the Export Administration Regulations (EAR), 15 CFR Parts 730 through 799, in performing work under this Agreement. In the absence of available license exemptions/exceptions, Partner shall be responsible for obtaining the appropriate licenses or other approvals, if required, for exports of hardware, technical data and software, or for the provision of technical assistance.

- (b) Partner shall be responsible for obtaining export licenses, if required, before utilizing foreign persons in the performance of work under this Agreement, including instances where the work is to be performed on-site at NASA and where the foreign person will have access to export-controlled technical data or software.
- (c) Partner will be responsible for all regulatory record keeping requirements associated with the use of licenses and license exemptions or exceptions.
- (d) Partner will be responsible for ensuring that the provisions of this Article 14 apply to its Related Entities.

ARTICLE 15. TERM OF AGREEMENT

This Agreement becomes effective upon the date of the last signature below and shall remain in effect until the completion of all obligations of both Parties hereto, or three (3) years from the date of the last signature, whichever comes first.

ARTICLE 16. RIGHT TO TERMINATE

Either Party may unilaterally terminate this Agreement by providing thirty (30) calendar days written notice to the other Party.

ARTICLE 17. CONTINUING OBLIGATIONS

The rights and obligations of the Parties that, by their nature, would continue beyond the expiration or termination of this Agreement, e.g., “Liability and Risk of Loss” and “Intellectual Property Rights” shall survive such expiration or termination of this Agreement.

ARTICLE 18. MANAGEMENT POINTS OF CONTACTS

The following personnel are designated as the principal points of contact between the Parties in the performance of this Agreement.

Technical Points of Contact:

NASA Lyndon B. Johnson Space Center

Paul Marshall
Orion Project Office
Mail Stop: ZV
2101 NASA Parkway
Houston, TX 77058
Phone: 281-483-0682
paul.f.marshall@nasa.gov

SRT-STEM Center

UTMB
Clifford W. Houston, Ph.D.
301 University Boulevard
Mail Route 0981
Galveston, TX 77555

ARTICLE 19. DISPUTE RESOLUTION

Except as otherwise provided in Article 6 entitled “Priority of Use,” Article 10 entitled “Intellectual Property Rights – Invention and Patent Rights” (for those activities governed by 37 CFR Part 404), and those situations where a pre-existing statutory or regulatory system exists (e.g., under the Freedom of Information Act, 5 U.S.C. § 552), all disputes concerning questions of fact or law arising under this Agreement shall be referred by the claimant in writing to the appropriate person identified in this Agreement as the “Management Points of Contact.” The persons identified as the “Management Points of Contact” for NASA and the Partner will consult and attempt to resolve all issues arising from the implementation of this Agreement. If they are unable to come to agreement on any issue, the dispute will be referred to the signatories to this Agreement, or their designees, for joint resolution. If the Parties remain unable to resolve the dispute, then the NASA signatory or that person’s designee, as applicable will issue a written decision that will be the final agency decision for the purpose of judicial review. Nothing in this section

limits or prevents either Party from pursuing any other right or remedy available by law upon the issuance of the final agency decision.

ARTICLE 20. MODIFICATIONS

Any modification to this Agreement shall be executed, in writing, and signed by an authorized representative of NASA and Partner. Any modification that creates an additional commitment of NASA or Partner resources must be signed by the original NASA or Partner signatory authority, or successor, or a higher level NASA or Partner official possessing original or delegated authority to make such a commitment.

ARTICLE 21. ASSIGNMENT

Neither this Agreement nor any interest arising under it will be assigned by Partner or NASA without the express written consent of the officials executing this Agreement.

ARTICLE 22. APPLICABLE LAW

U.S. Federal law and the laws of the State of Texas govern this Agreement for all purposes, including, but not limited to, determining the validity of the Agreement, the meaning of its provisions, and the rights, obligations and remedies of the Parties.

ARTICLE 23. INDEPENDENT RELATIONSHIP

This Agreement is not intended to constitute, create, give effect or otherwise recognize a joint venture, partnership, or formal business organization, or agency agreement of any kind, and the rights and obligations of the Parties shall be only those expressly set forth herein.

ARTICLE 24. SIGNATORY AUTHORITY

The signatories to this Agreement covenant and warrant that they have authority to execute this Agreement. By signing below, the undersigned agree to the above terms and conditions.

NATIONAL AERONAUTICS AND SPACE
ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER

THE UNIVERSITY OF TEXAS MEDICAL
BRANCH AT GALVESTON, for and on behalf of the
SOUTHEAST REGIONAL
T-STEM CENTER

BY: _____
Doug Cooke
Associate Administrator

BY: _____
William R. Elger, CPA
Executive Vice President and Chief
Business and Finance Officer

DATE: _____

DATE: _____

Content Reviewed

Appendix B.

Auxiliary Bus Control Unit (ABCU) Project Package¹³

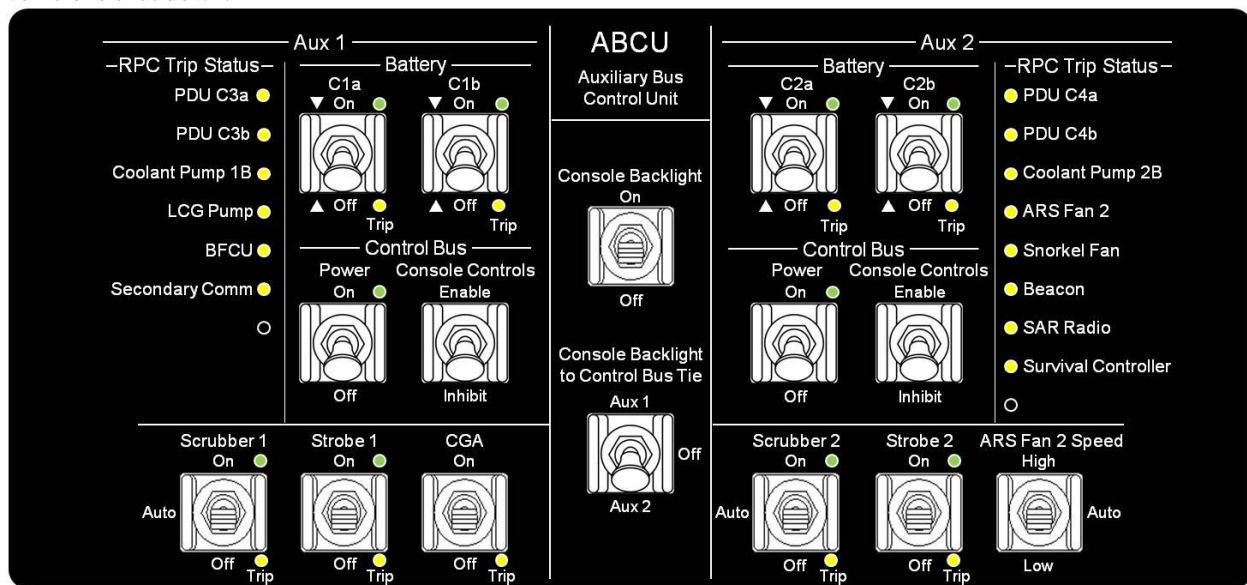
High Level Project Task:

Design, build, and deliver hardware simulating the Orion Auxiliary Bus Control Unit (ABCU). Details and requirements for this task are contained in this document.

ABCU Background

Concepts of Operations

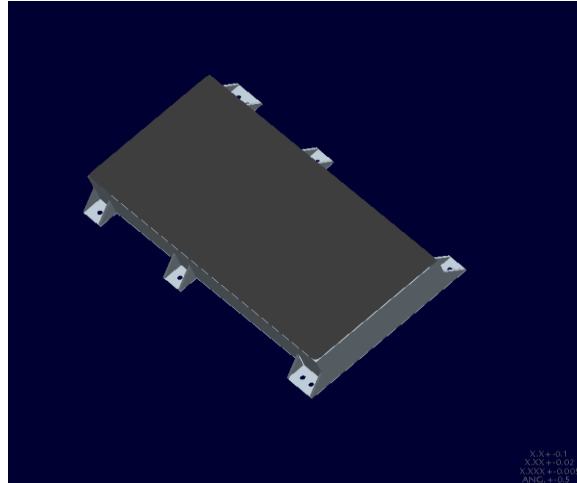
The Auxiliary Bus Control Unit (ABCU) is a switch panel mounted on the forward bulkhead (overhead) that controls power distribution to displays and controls on the main console. It also provides power and control to various equipment used for post-landing operations or emergency situations, when main electrical power to the vehicle is shut down.



ABCU front panel layout

The ABCU is normally only reconfigured just after the spacecraft reaches orbit and transitions from ascent to orbit mode and again at the end of the mission prior to deorbit to transition from orbit to entry mode. The crew must get out of the seats to reconfigure the panel, because it is out of reach when they are strapped in for ascent and entry.

The ABCU panel utilizes switches and LEDs to provide control and feedback on the power status of the applicable equipment. Each switch controls a remote power controller (RPC), a solid state power control and circuit protection device. Each RPC is instrumented with On/Off status and a Trip status that indicates if an electrical short has occurred which has automatically interrupted the circuit. Each switch and LED is labeled according to standardized nomenclature, font, color, and size rules to ensure both readability and minimization of errors in operation.



ABCU box shape

Mockup Hardware Planned Usage

In the Orion Medium Fidelity Mockup, the ABCU panel will be non-functional electrically, but should utilize flight-like movable switches, colored indicators, fonts, colors, etc. to the extent possible to support evaluation of reach and visibility of the panel from various locations and positions within the crew cabin. Dimensions of the box are also important, since this box fits among a collection of other equipment on the forward bulkhead and may represent an obstruction or kick hazard for both in-space and on-the-ground movement into and out of the vehicle. As such, the structure of the mockup panel must be robust enough to withstand inadvertent contact by crewmembers, emergency personnel, and equipment. This should be considered in selection of materials in the design of the mockup panel.

Orion ABCU Flight Design Model

The flight hardware of the ABCU has been designed by the Orion team and is modeled in the Computer Aided Design (CAD) software, ProEngineer. The ProE CAD model of the flight design ABCU is provided along with this package. We will work with the school if there is a preference for another CAD format.

ABCU Project Requirements

1. One Auxiliary Bus Control Unit mockup shall be provided with dimensional tolerance of $\pm 0.25''$
2. The design shall be based on the Orion ABCU flight design model provided
3. The mockup shall have operable switches, but may not be electrically functional
4. No hardware that is only internal to the ABCU is required, such as wiring, circuit boards, and other hardware
5. The weight of the ABCU and mounting hardware is not to exceed 20 lbs. with a goal weight of 5 lbs. or less.
6. Once delivered, the ABCU will be mounted to the Forward Bulkhead (ceiling) in the Medium Fidelity Mockup. The Forward Bulkhead is 5/16" A36 steel plate.
7. The Installation method shall be designed and the associated hardware shall be provided along with the completed ABCU.
8. The installation method shall assume that the mockup forward bulkhead will be drilled and tapped to accept the mounting screws.
9. The assembly and installation shall be designed for a safety factor of 3 for yield, or safety factor of 4 for ultimate. This safety factor shall be incorporated into the selection of materials, assembly methods, and selection of installation fasteners, regarding the installation bolt size, as compared to its breaking strength.

10. The hardware may be made of any combination of metal, wood, or plastic (including Fuse Deposition Modeler (FDM) type construction). Metal is preferred.
11. The exterior surface of any wood hardware shall be painted with fire retardant paint
12. Any carbon steel shall be primed and painted to avoid rust
13. Metal surfaces may be painted or anodized.
14. Connectors and switches will be provided by NASA.
15. All exposed edges shall be void of sharp edges to protect the people and hardware, such as spacesuits, that will be around the mockups. Edges and corners shall incorporate a 0.25” minimum radius. Edges inside the box and in hard to get to locations, when installed, do not have to meet this edge radius, but shall at a minimum be broken.
16. All exposed surfaces shall be free of burrs, splinters, or other unintended protrusions or hazards that may result in injury or damage to spacesuits or other equipment that comes in contact with these surfaces
17. Appropriate flight design colors, fonts, font sizes, line weights, etc. shall be used for all labels, indicators, backgrounds, and other components. The front panel image in this document shall be used to define these attributes, unless indicated otherwise.
18. No later than the delivery of the ABCU, the final design model, drawings, structural assessment, and any other helpful documentation shall be provided to NASA.

References

¹Office of the Press Secretary., “President Obama Launches “Educate to Innovate” Campaign for Excellence in Science, Technology, Engineering & Math (Stem) Education,” *Statements & Releases*, URL: <http://www.whitehouse.gov/the-press-office/president-obama-launches-educate-innovate-campaign-excellence-science-technology-en> [cited 23 November 2009]

²Canright, Shelley., “About NASA’s Education Program,” *About NASA Education*, URL: <http://www.nasa.gov/offices/education/about/index.html> [cited 1 December 2010].

³Townsend, Jason., “Participatory Exploration Office,” *Open Government Initiative*, URL: <http://www.nasa.gov/open/plan/peo.html> [cited 26 April 2010].

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⁵Petty, John Ira., “High School Students Build Hardware for NASA,” *Shuttle & Station News Feature*, URL: <http://www.nasa.gov/vision/space/preparingtravel/hunch.html> [cited 30 November 2007].

⁶Hale, Stacy., “HUNCH,” *HUNCH*, URL: <http://www.nasahunch.com/> [Cited 20 November 2010].

⁷Texas High School Project T-STEM Centers., “The Coalition of T-STEM Centers,” *Texas High School Project*, URL: <http://tstem.thsp.org/cms/One8851.html?portalId=292873&pageId=9901379> [cited 21 November 2010]

⁸Mullins, Debbie., “About the Design Challenge,” *Texas Space Grant Consortium*, URL: <http://www.tsgc.utexas.edu/challenge/program.html> [cited 21 November 2010]

⁹Friant, Melvin., “Contingency Gas Analyzer,” Students Shaping America’s Next Spacecraft, NASA Lyndon B. Johnson Space Center, Houston, Texas, 2010.

¹⁰Moncur, Michael., “Quotation #5082 from Cole’s Quotables,” Quotation Details, *The Quotations Page*, URL: <http://www.quotationspage.com/quote/5082.html> [cited 5 December 2010].

¹¹Kennedy, John F., (1917-1963) Thirty-fifth President of the USA

¹²Kuenzi, Jeffrey J., “Science, Technology, Engineering, and Mathematics (STEM) Education: Background, Federal Policy, and Legislative Action,” Congressional Research Service, RL33434, March 2008.

¹³Friant, Melvin., “Auxiliary Bus Control Unit (ABCU) Project Package” Students Shaping America’s Next Spacecraft, NASA Lyndon B. Johnson Space Center, Houston, Texas, 2010.

¹⁴Copeland, Barry., “Nonreimbursable Space Act Agreement Between NASA and the University Texas Medical Branch at Galveston for and on Behalf of Southeast Regional T-STEM Center,” Students Shaping America’s Next Spacecraft, NASA Lyndon B. Johnson Space Center, Houston, Texas, 2010.